CLAIMS

1. An object location system for locating an object having an RFID tag, the object location system comprising:

an RFID reader, the RFID reader transmitting a plurality of transmitted signals to the RFID tag and receiving a plurality of backscatter modulated signals from the RFID tag, at least two of the plurality of transmitted signals having a different fundamental frequency with a randomly selected frequency difference; and

a distance calculator, the distance calculator determining a phase for each of the plurality of backscatter modulated signals from the RFID tag, the distance calculator determining a distance to the RFID tag by determining a rate of change of the phase in the plurality of backscatter modulated signals with respect to rate of change in the fundamental frequency of the plurality of transmitted signals.

2. The system of claim 1 wherein the RFID reader continues to transmit additional transmitted signals and receive additional backscatter modulated signals and wherein the distance calculator continues to determine a phase for each of the additional backscatter modulated signals received and uses the phase for each additional backscatter modulated signal to determine the distance from the RFID reader to the RFID tag is until the distance is computed within a specified level of accuracy.

3. The system of claim 1 wherein the rate of change of the phase in the plurality of backscatter modulated signals with respect to a rate of change in the fundamental frequency of the plurality of transmitted signals is determined by performing a linear trend fit of the phase in the plurality of backscatter modulated signals versus the fundamental frequency of the plurality of transmitted signals.

4. The system of claim 3 wherein performing a linear trend fit comprises performing a least squares fit.

5. The system of claim 1 wherein the distance calculator determines the phase difference by unwrapping relative phase difference measurements to result in a substantially linear phase trend.

6. The system of claim 1 wherein the RFID reader comprises a mobile reader.

7. The system of claim 1 wherein the distance calculator is implemented as part of the RFID reader.

8. The system of claim 1 wherein the distance calculator determines the phase in the plurality of backscatter modulated signals by demodulating each of the plurality of backscatter modulated signals into an I channel and a Q channel and measuring an AC amplitude of the I channel and an AC amplitude of the Q channel.

9. The system of claim 1 wherein the distance calculator determines the phase in the plurality of backscatter modulated signals by demodulating each of the plurality of backscatter modulated signals into an I channel and a Q channel and utilizing a rotation matrix to minimize a portion of signal in the Q channel versus a portion of signal in the I channel.

10. An object location system for locating an object having an RFID tag, the object location system comprising:

an RFID reader, the RFID reader transmitting at least three transmitted signals to the RFID tag and receiving at least three backscatter modulated signals from the RFID tag, wherein at least two of the at least three transmitted signals have a different fundamental frequency; and

a distance calculator, the distance calculator determining a phase for each of the at least three backscatter modulated signals from the RFID tag, the distance calculator determining a distance to the RFID tag by performing a linear trend fit of the phase in the at least three backscatter modulated signals and the fundamental frequency of the at least three transmitted signals to determine a rate of change of the phase with respect to a rate of change of the fundamental frequency.

11. The system of claim 10 wherein the RFID reader continues to transmit additional transmitted signals and receive additional backscatter modulated signals and wherein the distance calculator continues to determine a phase for each of the additional backscatter modulated signals received and uses the phase for each additional backscatter modulated signal to determine the distance from the RFID reader to the RFID tag is until the distance is computed within a specified level of accuracy.

12. The system of claim 10 wherein the linear trend fit of the phase in the at least three backscatter modulated signals and the fundamental frequency of the at least three transmitted signals is performed using a least squares fit.

13. The system of claim 10 wherein the at least two of the at least three transmitted signals have a randomly selected frequency difference.

14. The system of claim 10 wherein the at least two of the at least three transmitted signals have a frequency selected by selecting a next available frequency channel using a listen before transmit procedure.

15. The system of claim 10 wherein the distance calculator determines the phase difference by unwrapping relative phase difference measurements to result in a substantially linear phase trend.

16. The system of claim 10 wherein the RFID reader comprises a mobile reader.

17. The system of claim 10 wherein the distance calculator is implemented as part of the RFID reader.

18. The system of claim 10 wherein the distance calculator determines the phase in the at least three backscatter modulated signals by demodulating each of the at least three backscatter modulated signals into an I channel and a Q channel and measuring an AC amplitude of the I channel and an AC amplitude of the Q channel.

19. The system of claim 10 wherein the distance calculator determines the phase in the at least three backscatter modulated signals by demodulating each of the at least three backscatter modulated signals into an I channel and a Q channel and utilizing a rotation matrix to minimize a portion of signal in the Q channel versus a portion of signal in the I channel.

20. A method of locating an object having an RFID tag, the method comprising the steps of:

addressing the RFID tag using an RFID reader, the addressing of the RFID tag putting the RFID tag into a responsive state;

transmitting a plurality of transmitted signals from the RFID reader to the RFID tag, the plurality of transmitted signals having a randomly selected different fundamental frequency difference;

receiving a plurality of backscatter modulated signals from the RFID tag;

determining a phase for each of the plurality of backscatter modulated signals; and

computing a distance to the RFID tag by determining a rate of change of the phase in the plurality of backscatter modulated signals with respect to a rate of change in the fundamental frequency of the plurality of transmitted signals.

21. The method of claim 20 wherein the steps of transmitting a plurality of transmitted signals, receiving a plurality of backscatter modulated signals, and determining a phase in the plurality of backscatter modulated signals comprises transmitting, receiving and determining a phase for additional transmitted signals and backscatter modulated signals until the step of computing the distance to the RFID tag determines the distance within a specified level of accuracy.

22. The method of claim 20 wherein the step of computing a distance to the RFID tag by determining a rate of change of the phase in the plurality of backscatter modulated signals with respect to a rate of change in the fundamental frequency comprises performing a linear trend fit.

23. The method of claim 22 wherein the linear trend fit comprises a least squares fit.

24. The method of claim 20 wherein the step of determining a phase for each of the plurality of backscatter modulated signals comprises demodulating each of the plurality of backscatter modulated signals into an I channel and a Q channel and measuring an AC amplitude of the I channel and an AC amplitude of the Q channel and by determining a relative phase for each of the plurality of backscatter modulated signals by taking an arctangent of the Q channel AC amplitude divided by the I channel AC amplitude.

25. The method of claim 20 wherein the step of determining a phase for each of the plurality of backscatter modulated signals comprises demodulating the received plurality of backscatter modulated signals into an I channel and a Q channel and utilizing a rotation matrix to minimize a portion of signal in the Q channel versus a portion of signal in the I channel.

26. The method of claim 20 wherein the step of determining a phase for each of the plurality of backscatter modulated signals comprises unwrapping relative phase difference measurements to result in a substantially linear phase trend.

27. The method of claim 20 wherein the step of transmitting a plurality of transmitted signals from the RFID reader to the RFID tag comprises transmitting from an array of RFID readers, and wherein the step of receiving a plurality of backscatter modulated signals from the RFID tag comprises receiving the plurality of backscatter modulated signals at the array of RFID readers, and wherein the step of computing a distance to the RFID tag comprises computing a distance from the RFID tag to each of the array of RFID readers.

28. The method of claim 27 wherein at least one of the array of RFID readers comprises a mobile RFID reader, and wherein the mobile reader includes an RFID tag used determine a location of the mobile reader.

29. The method of claim 20 wherein the RFID reader comprises a mobile RFID reader.

30. The method of claim 20 wherein the step computing a distance to the RFID tag by determining a rate of change of the phase in the plurality of backscatter modulated signals with respect to a rate of change in the fundamental frequency of the plurality of transmitted signals comprises using at least three determined phases and at least three fundamental frequencies to calculate the rate of change.

31. A method of locating an object having an RFID tag, the method comprising the steps of:

addressing the RFID tag using an RFID reader, the addressing of the RFID tag putting the RFID tag into a responsive state;

transmitting at least three transmitted signals from the RFID reader to the RFID tag, wherein at least two of the at least three transmitted signals have a different fundamental frequency;

receiving at least three backscatter modulated signals from the RFID tag;

determining a phase for each of the at least three backscatter modulated signals; and

computing a distance to the RFID tag by performing a linear trend fit of the phase in the at least three backscatter modulated signals and the fundamental frequency of the at least three transmitted signals to determine a rate of change of the phase with respect to a rate of change of the fundamental frequency.

32. The method of claim 31 wherein the steps of transmitting at least three transmitted signals, receiving at least three backscatter modulated signals, and determining a phase in the at least thee backscatter modulated signals comprises transmitting, receiving and determining a phase for additional transmitted signals and backscatter modulated signals until the step of computing the distance to the RFID tag determines the distance within a specified level of accuracy.

33. The method of claim 31 wherein the linear trend fit comprises a least squares fit.

34. The method of claim 31 wherein the step of determining a phase for each of the at least three backscatter modulated signals comprises demodulating each of the at least three backscatter modulated signals into an I channel and a Q channel and measuring an AC amplitude of the I channel and an AC amplitude of the Q channel and by determining a relative phase for each of the at lest three backscatter modulated signals by taking an arctangent of the Q channel AC amplitude divided by the I channel AC amplitude.

35. The method of claim 31 wherein the step of determining a phase for each of the at least three backscatter modulated signals comprises demodulating the received at least three backscatter modulated signals into an I channel and a Q channel and utilizing a rotation matrix to minimize a portion of signal in the Q channel versus a portion of signal in the I channel.

36. The method of claim 31 wherein the step of determining a phase for each of the at least three backscatter modulated signals comprises unwrapping relative phase measurements to result in a substantially linear phase trend.

37. The method of claim 31 wherein the step of transmitting at least three transmitted signals from the RFID reader to the RFID tag comprises transmitting at least three transmitted signals each RFID reader in an array of RFID readers, and wherein the step of receiving at least three backscatter modulated signals from the RFID tag comprises receiving at least three backscatter modulated signals at each RFID reader in the array of RFID readers, and wherein the step of computing a distance to the RFID tag comprises computing a distance from the RFID tag to each RFID reader in the array of RFID readers.

38. The method of claim 37 wherein at least one of the array of RFID readers comprises a mobile RFID reader, and wherein the mobile reader includes an RFID tag used determine a location of the mobile reader.

39. The method of claim 31 wherein the RFID reader comprises a mobile RFID reader.

40. The method of claim 31 wherein the at least three transmitted signals have a randomly selected fundamental frequency difference.

41. The method of claim 31 wherein the at least three transmitted signals have a frequency frequency selected by selecting a next available frequency channel using a listen before transmit procedure.

42. An object location system for locating objects having RFID tags, the object location system comprising:

an array of RFID readers distributed around an area, each of the array of RFID readers transmitting at least three transmitted signals to an RFID tag and receiving at least three backscatter modulated signals from the RFID tag, wherein the at least three transmitted signals from each RFID reader have a fundamental frequency with a randomly selected fundamental frequency difference; and

a distance calculator, the distance calculator determining a phase of the at least three backscatter modulated signals received at each RFID reader, the distance calculator determining a distance from each RFID reader by performing a linear trend fit of the phase in the at least three backscatter modulated signals and the fundamental frequency of the at least three transmitted signals to determine a rate of change of the phase with respect to a rate of change of the fundamental frequency.

43. The system of claim 42 wherein each of the array of RFID readers continues to transmit additional transmitted signals having a fundament frequency and continues to receive additional backscatter modulated signals and wherein the distance calculator continues to determine a phase for each of the additional backscatter modulated signals received and uses the fundamental frequency for each additional transmitted signal and uses the phase for each additional backscatter modulated signal to determine the distance each RFID reader to the tag until the distance from that RFID reader to the RFID tag is computed within a specified level of accuracy.

44. The system of claim 42 wherein the linear trend fit of the phase in the at least three backscatter modulated signals and the fundamental frequency of the at least three transmitted signals is performed using a least squares fit.

45. The system of claim 42 wherein the array of RFID readers includes at least one mobile reader.

46. The system of claim 42 wherein the at least one mobile reader includes a mobile reader RFID tag, and wherein other of the array of RFID readers are used to determine a location of the mobile reader using the mobile reader RFID tag such that the location of the mobile reader can be used to determine a location of other RFID tags.

47. The system of claim 42 wherein the array of RFID readers includes a plurality of RFID antennas coupled to an RFID transceiver through a switch.

48. The system of claim 42 wherein the distance calculator determines the phase in the at least three backscatter modulated signals by demodulating the at least three backscatter modulated signals into an I channel and a Q channel and measuring an AC amplitude of the I channel and an AC amplitude of the Q channel and by determining a relative phase for each of the at least three backscatter modulated signals by taking an arctangent of the Q channel AC amplitude divided by the I channel AC amplitude for each of the at least three backscatter modulated signals.

49. The system of claim 42 wherein the distance calculator determines the phase in the at least three backscatter modulated signals by demodulating the at least three backscatter modulated signals into an I channel and a Q channel and utilizing a rotation matrix to minimize a portion of signal in the Q channel versus a portion of signal in the I channel.

50. The system of claim 42 wherein the distance calculator determines the phase in the plurality of backscatter modulated signals by unwrapping a plurality of relative phase measurements to result in a substantially linear phase trend.

51. The system of claim 42 wherein the distance calculator is implemented as part of the plurality of RFID readers.